AN OCCURRENCE OF IMPSONITE IN WESTERN AUSTRALIA.

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I.—INTRODUCTION.

At the end of June, 1920, a sample was received at the Geological Survey Office, Perth, from Mr. Hobler, Engineer for Commonwealth Railways, who stated that it had been handed to him while he was accompanying the Ministerial party in Kimberley.

On the same day an identical sample was received through the Honourable Mr. Colebatch, who in a covering letter stated that it had been given to him by a Mr. Walter Oakes, of Ningbing Station, Wyndham, and that Mr. Oakes believed it to be oil shale or coal. There is no doubt that both this sample and that of Mr. Hobler came from the same spot, viz., the one discovered by Mr. Oakes.

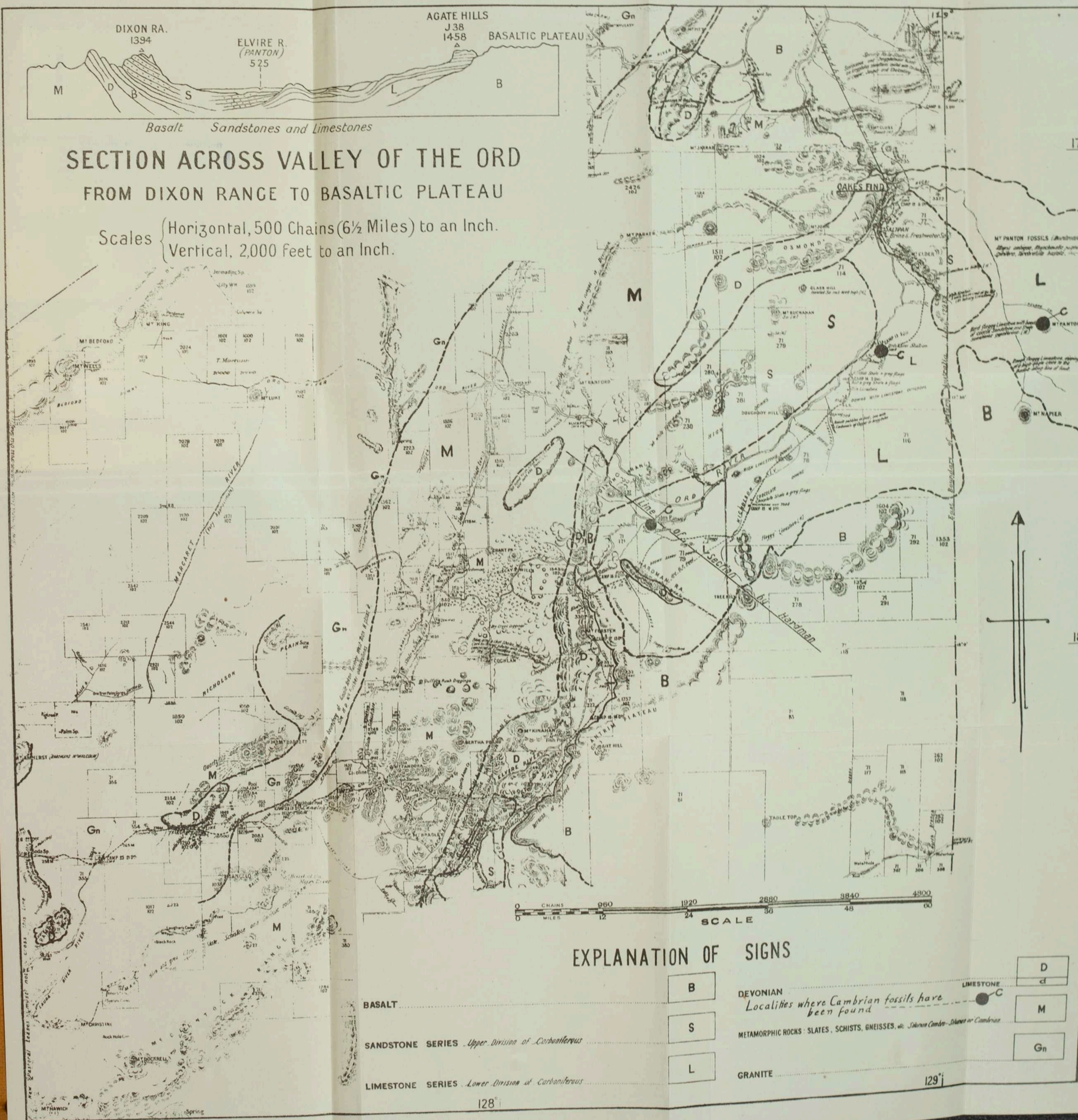
Some time later, about 29th September, another sample of the same material was received from Mr. M. P. Durack, who said that he had obtained it from a locality close to Oakes' Find, near the junction of the Ord and Negri Rivers, East Kimberley.

As an examination of all the specimens showed that the material was of sufficient importance to warrant further investigation, Mr. Blatchford, who was at the time in West Kimberley, was instructed to inspect the area in which the finds were made. He not only confirmed the discovery of the material by Mr. Oakes at the junction of the Ord and Negri Rivers, but found that years previously it had been handled unknowingly by man in a well, near Texas Homestead, on the bank of the Ord River, some five miles up from the junction with the Negri, and he concluded, therefore, that in all probability the material occurred at least at intervals throughout these five miles. The location of the finds is marked on the accompanying plan. (Plate I.)

Plate I.

GEOLOGICAL MAP
OF
PART OF EAST KIMBERLEY DISTRICT
by

E. T. Hardman and R. L. Jack



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II.—NATURE OF THE MATERIAL.

All the samples sent in are identical. They consist of a black mineral with a brilliant lustre, which is very brittle, combustible and mostly seamed with cracks. At first sight, it rather closely resembles anthracite coal, but an investigation of its physical and chemical characters proves that it is not a variety of coal, but an asphaltum. Through the courtesy of Dr. Simpson I am able to give the following more important physical and chemical characters of the mineral: —It ignites and burns freely, and does not melt on heating even above 300 deg. C, decomposition taking place without any signs of softening. Specially selected clean fragments had a density of 1.154, but many fragments had densities rising from this figure to 1.20, owing to adhering small quantities of calcite and rock. The calorific value of the purest material was 16573 B.T.U. Ultimate analysis of Mr. M. P. Durack's specimen gave:—

	per cent.
C	89·40
H	7·26
S	·68
N	·41
O	2·25
	100·00
Ash	·43

Proximate analysis gave:—

	Per cent.
Moisture	0·37
Volatile	41·54
Fixed Carbon	56·27
Ash	1·82*
	100·00

Moderately low temperature distillation showed the volatile matter to consist of:—

	per cent.
Water	1·74
Oil	19·89
Gas	19·91
	41·54 (as in the proximate analysis).

Analysis of original impsonite from Indian Territory, U.S.A. (reference later):—

	per cent.
C	86·57
H	7·26
S	1·38
N	1·48
O	2·00
	98·69
Ash	1·31

* The proximate analysis was made on a different lot of fragments from those used in the ultimate analysis. Hence the slight difference in results of determination of the ash.

The gas burnt freely with a slightly luminous flame. The oil had a density of 0.758 at 25 deg. C., it was dark-brown in colour, translucent, fluorescent and of low viscosity. The water which distilled over was distinctly acid in reaction.

Digestion of the asphaltum with carbon bisulphide in the cold extracted a bright black bitumen, amounting to 15.38 per cent. of the whole in the case of Mr. Durack's sample.

Comparison of these characters with those of similar minerals from America, shows beyond doubt that the mineral is a solid asphaltite that can be included under the term "Glance Pitch," or "Manjak," used as a group name. It most closely agrees with the variety Impsonite, first described over twenty years ago from East Indian Territory, U.S.A.*

The importance of the asphaltites and closely related substances lies in the fact that they are indications of the past or present existence of petroleum in the neighbourhood in which they are found. They are produced by the drying or inspissation of petroleum, *i.e.*, as the residual products of natural distillation in which the more volatile fluids have been scattered, the heavier oil and sulphur compounds concentrated and some degree of polymerisation has taken place. Between oil and asphalt, there are all stages ranging from the liquid to the solid state, the differences between the stages being largely due to differences in composition of the original oil and to differences in the degree of drying. The comparative hardness and the extent to which chemical alteration has taken place in the mineral from Oakes' Find prove that it is of considerable geological age.

III.—MODE OF OCCURRENCE OF THE MINERAL.

The amount of knowledge at hand up to the present about the occurrence of the mineral is small, consisting only of what may be deduced from a study of the geological maps of the Kimberley Division, prepared many years ago by Mr. E. T. Hardman, and at a later date by Dr. Jack, from the consideration of a few other published reports on some aspect of the geology of the Ord River District, and of the facts that may be ascertained by an investigation of the material in which the mineral is found. The information that may be derived from the maps, sections, and other published reports, will be considered later.

The material in which the impsonite occurs is a fine textured rock, which in hand specimens ranges in colour from dark-green when nearly fresh, through dull grayish-green to brownish-yellow, the colour depending on the degree of alteration. There are at least

* An albertite-like asphalt in the Choctaw Nation, Indian Territory, U.S.A., by Joseph A. Taff: Am. Journ. Gei, Sept., 1898, 4th Series, Vol. VIII., p. 224.

two varieties of it, one massive or showing only slight signs of fracturing, the other so fractured as to be virtually a breccia and consisting of fragments of comparatively fresh rock separated by more decomposed and broken down material. It may be asserted that the fracturing is due to the amount of blasting that has been necessary to get the specimens, but the appearance of the surfaces, the shear planes and the cracks as well as the occurrence of the mineral along these cracks and planes shows clearly that this cannot be the case. In some specimens, the massive variety shows a clean-cut junction with a sheared rock, and along the surfaces of separation, are well-marked slickensides. In others, the massive variety is more cracked and disintegrated than sheared.

The outstanding features of the rock are its extremely vesicular character and the fact that quite a number of vesicles are filled with impsonite. The vesicles range in size from that of a pin-head to that of a walnut. Some are spherical, others elliptical, and others again are almost disc-shaped. The material filling them is different in different vesiles and consists:—

(a) of calcite, which fills the largest.

(b) of dull greenish chlorite, or of calcite and a border of greenish chlorite.

(c) of quartz in shot-like form.

(d) of impsonite.

(e) of impsonite and calcite with or without pyrites, the calcite being in some partly bordered by the black mineral, in others surrounding the black mineral, and in others occurring along numerous cracks in it.

Some of the vesicles are only partly filled, others are quite empty.

The sheared or partly brecciated rock is by no means so noticeably vesicular as the massive, though in the comparatively fresh fragments in it a few small vesicles can be made out. On the other hand, this fractured rock is much more heavily impregnated with impsonite than the massive rock, the mineral occurring not in holes as in the latter but in large and small patches and strings.

Owing to the fineness of texture of the rock, the extent to which the green chlorite binds the felspar laths of the rock-mass, and to the fact that though the vesicles are in places fairly numerous they are not connected with one another, the effective pore space of the rock and consequently its capacity for taking up and storing fluids is small except where shearing is pronounced.

Nevertheless, the effective porosity of the greenish somewhat decomposed but massive rock, determined by the method of alternately heating and cooling the water in which it is immersed for a period of four or five days, is appreciable, amounting to 3.43 per cent. According to E. R. Buckley* the effective porosities of various building stones (determined by the same method) are as follows:—

	Limits.	Average effective porosity.
14 samples of granite ..	0.108 to 0.519	0.332
11 samples of limestone ..	0.53 to 13.36	4.43
16 samples of sandstone ..	4.81 to 28.28	14.46

The effective porosity, therefore, of the somewhat decomposed rock compares favourably with the average for limestones, and is very considerably greater than that for granite.

The rock itself, both massive and sheared, is a vesicular basaltic dolerite. In section it consists of a loose plexus of thin twinned laths of felspar more or less clouded, between which is either a fine granular dust or greenish chlorite due to the decomposition of pre-existing augite. Small patches wholly made up of greenish chlorite occur scattered through the mass.

The impsonite occurs in the rock in a variety of ways:—

(a) in vesicles filling the whole of the cavity and with a border of chloritic material between it and the basalt (Plate II.)

(b) in vesicles with calcite, in some cases as a border to the latter but extending only round one end of an elliptical vesicle, in others occupying the interior of the hole and surrounded by calcite, in others again showing a network of cracks which are filled with calcite.

(c) in very thin strings along cracks in the more or less massive rock.

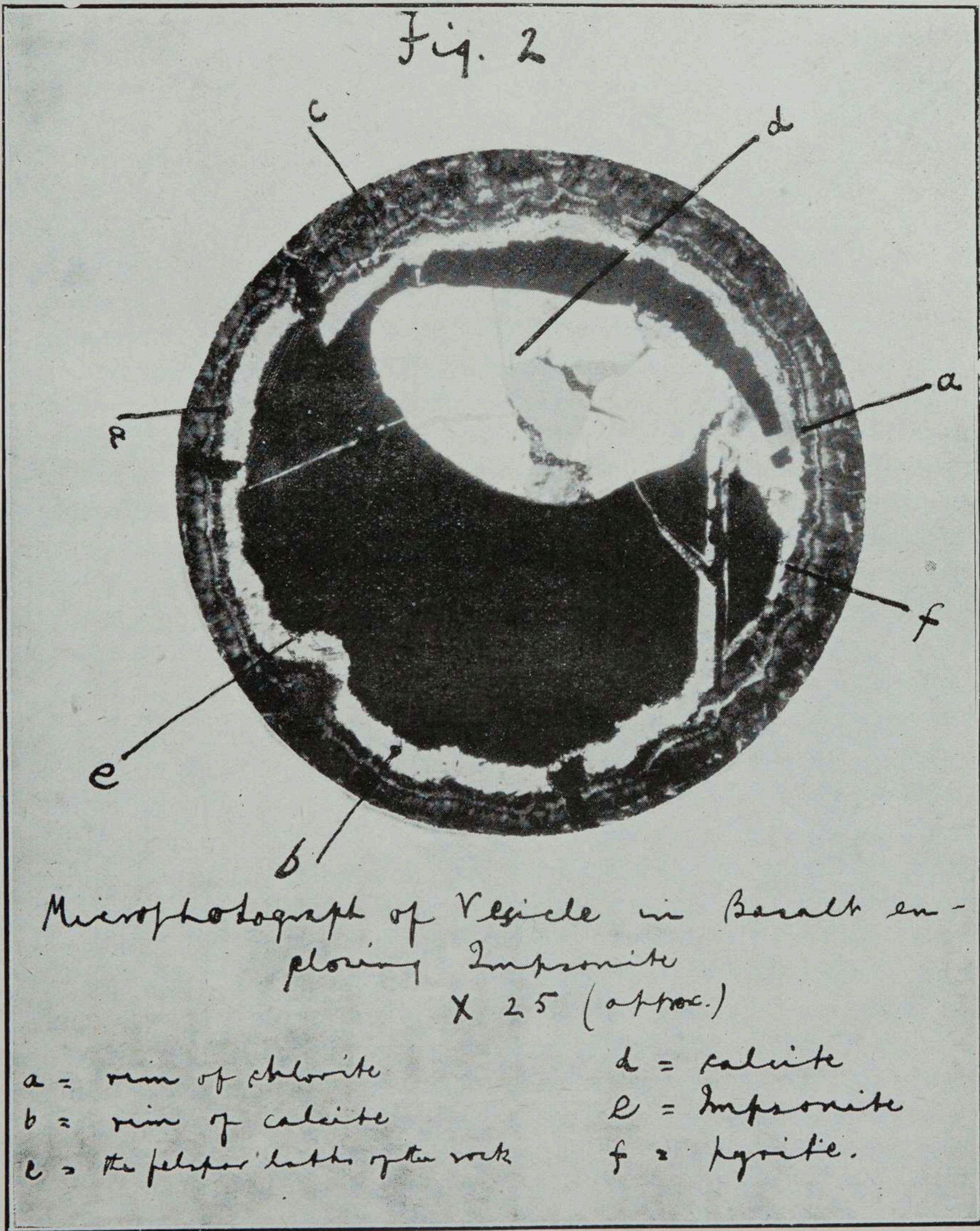
(d) in large strings and patches in the sheared rock, occurring along the cracks and shear planes and in one instance in a comparatively thick layer along a probable joint plane.

With the mineral in some of the amygdaloids is a small amount of pyrites, and this mineral is scattered in small grains through the decomposed and sheared rock.

Microscopical examination of the junction between the two varieties of rock shows the presence of a sheared zone filled with fragments of the basalt surrounded by granular quartz (the remains of a vesicle), granular felspar and granular calcite, black strings of impsonite intimately associated with the calcite and also occur-

* Buckley, E. R.: "Building and Ornamental Stones of Wisconsin."

Plate II.



Impsonite in Basalt.

ring along cracks, and fragments of the rock almost black as though they had been partly impregnated with the mineral.

Sections of the black filling of the vesicles show it to be quite homogeneous, to contain no remains of any silicate or other mineral, though chlorite occurs round it and calcite both round it and through it.

The relations of the impsonite to the calcite are difficult to account for. As it occurs as a border to calcite that fills some of the vesicles, it would appear to have penetrated the rock after the formation of the calcite in the holes. On the other hand, its occurrence surrounded by calcite and also reticulated by calcite strings tends to show that the calcite was later than the black mineral. As the limestone occurs immediately above the basalt, some of the calcite fillings—especially the larger—may easily be due to carbonate solutions from the limestone which have detached the impsonite from the wall of the holes and on recrystallising have surrounded it. Another and perhaps more correct explanation is that the black mineral formerly existed in the holes in liquid form, that, as in time, some of the volatile hydracarbons evaporated, the residuum solidified in a smaller space and the holes were entered by carbonate solutions which filled up all cracks existing in the mineral, and may even have floated off the black residuum.

IV.—GEOLOGICAL POSITION.

The general geology of the locality of the find and of the surrounding district was first mapped by Hardman in 1885, and later in 1906 by Dr. Jack, whose map was naturally to a large extent based on that of Hardman. The work of these two geologists, though differing to some extent in minor details, has up till quite recently been accepted as a correct exposition of the structure and stratigraphy of the district, and even yet, though as will be shown some modification of the mapping of the limestone is necessary, the work must be accepted as remarkably accurate when account is taken of all the difficulties both men encountered. According to Hardman,* along the western side of the Ord River and extending eastward on the south side of the Negri River are two belts of rock consisting chiefly of sandstone and grits. These form the higher ground and may be seen as flat-topped tablelands. The geological age of this formation has been placed as Upper Carboniferous. Immediately underlying these sandstones and grits are fairly thick limestone beds which extend beyond the flanks of the first series, particularly to the east and south. These limestones are Lower Carboniferous. Over a great part of the country they

* Report on the Geology of the Kimberley District: E. T. Hardman, 1885, Perth, by Authority.

outcrop in bare masses, cut through by gullies and forming cliffs in which the stratification, dipping in various directions at a low angle, can be seen very distinctly. Under the limestone is a very extensive basalt sheet which extends for miles to the north, south and east (see the accompany plans and section). There is no evidence, so far as observations have gone, of contact metamorphism in the limestone, a fact which, taken in conjunction with the vesicular nature of the basalt, renders it improbable that the basalt is intrusive. Underlying the basalt are older sandstones, grits, shales, conglomerates, etc., probably of Devonian Age, which rest unconformably on still older slates, schists and gneisses possibly Lower Silurian or Upper Cambrian in Age. The stratigraphical relations of the rocks according to Hardman are shown succinctly in the accompanying section (Fig. 1).

It is clear, then, from the plans and section that according to Hardman and Jack, the limestone is Lower Carboniferous, the basalt (in which the impsonite is found) occurs as a sheet under this limestone, and that under the basalt are rocks probably of Devonian Age. It follows, therefore, that the basalt is either Upper Devonian or Lower Carboniferous in Age.

Now Hardman during the course of his explorations in 1883-1884 collected a suite of fossils from the bed of the Elvire River* to the south of Survey Station Z27 near his base line W.B.-E.B. in rocks which though without a symbol on his map must be according to the colour given them either Lower Carboniferous or Devonian, and which according to Dr. Jack's map are Lower Carboniferous. These fossils were examined by Mr. E. Etheridge, Mr. W. H. Foord and Dr. Henry Woodward, and determined as part of an Olenellus, Salterella Hardmani and numerous pteropods, *i.e.*, fossils of undoubted Cambrian age. Further, Hardman also collected fossils from the Ord River, five miles below its junction with the Elvire† opposite J.38 and at Mount Panton just east of the Western Australian border, and these also were subsequently determined as of Cambrian age.

Moreover, in 1909, Mr. H. W. B. Talbot had occasion to visit the Orde River, and from the upper stratum of limestone in a cliff near Ord River Station consisting of limestones and shales he collected a fossil which was subsequently determined as Salterella Hardmani, *i.e.*, of Cambrian age. According to Mr. Maitland‡ strata similar to those near Ord River Station extend from the Hardman Range to the Osmond Range in the north. Both Hardman and Jack have this area mapped as Carboniferous or Devonian.

* Geology of Western Australia: Mining Handbook, by A. Gibb Maitland, Perth, by Authority.

† Geology of Western Australia: By A. Gibb-Maitland, loc. cit. This locality is virtually the same as that given for the previous find.

‡ Loc. cit

The outcrop of vesicular basalt in the bed of the river near the junction of the Ord and the Negri, Hardman's map shows correctly, and Jack's map would be accurate in this particular if the margin of the basalt were extended a little further south.

It is quite evident, therefore, that although both Hardman and Jack have mapped the limestones that extend from north of Mount Panton in a south-westerly direction along the Ord River to beyond the Hardman Range as Lower Carboniferous, these rocks cannot all be of this age. In at least three distinct localities, viz., in the bed of the Elvire River south of Survey Station Z27, at Mount Panton just east of the Western Australian border, and from the cliffs of the Ord River near Ord River Station, the limestones are from their fossil contents beyond question of Cambrian age. As according to Hardman undoubted Carboniferous limestones do occur, *e.g.*, near Mount Panton,* it follows that the limestones of the district are of two ages, Lower Carboniferous and Cambrian, and, in default of additional evidence as to their stratigraphical relations, that the former rests unconformably on the latter.

The maps of both Hardman and Jack, then, should be amended to show the occurrence of Cambrian limestones at Mount Panton and in the valley of the Ord River, though, as the actual size of the outcrop of Cambrian limestone is not known, it is not yet possible to separate the latter from the Lower Carboniferous with any approach to accuracy. In particular, Hardman's section across the valley of the Ord from Dixon Range to the Basaltic Plateau must be amended to show the presence of Cambrian limestone under the Devonian (and Silurian) and outcropping in the valley of the Ord River. It must be noted that, though these alterations are now known to be necessary, it is scarcely the fault of either Hardman or Jack that they should be so, for Hardman's report was published long before his fossils were determined, and, as Jack's investigations in the Kimberley Division were chiefly concerned with locating possible artesian water basins, he naturally assumed the accuracy of a considerable part of Hardman's results.

The important feature of the presence of both Cambrian and Lower Carboniferous limestones in the Ord River valley is the extent to which it affects the age of the impsonite-bearing basalt. Up to the present it has been accepted without question that Hardman's section across the valley of the Ord is correct, and consequently that the basalt is of Lower Carboniferous or Upper Devonian age. There is, however, now introduced the possibility of the limestone being of Cambrian age, particularly as Cambrian limestones are proved to outcrop in two localities in the valley of

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* There is good reason, however, for believing that the locality labels of Hardman's fossils have been seriously mixed up, and there is at least a possibility that the limestone of the whole of the Mount Panton District and of large areas to the South-West of it is of Cambrian age.

the Ord. If this should be the case, then the basalt which occurs under the limestone, and which, owing to its strongly vesicular character, can scarcely be either a sill or a dyke, would be of Lower Cambrian age, and the outlook for the discovery of payable petroleum in the vicinity would be anything but favourable. Moreover, amygdaloidal basalts apparently similar to those at Oakes' Find occur in the Northern Territory, and according to Woolnough* they are to be regarded as of Lower Cambrian age.

On the other hand, as Hardman had with little doubt some grounds both palæontological and lithological for mapping the limestones as Lower Carboniferous,† it is probable that the limestone overlying the basalt is of this age, that the Cambrian limestone outcrops only in a few places of which the neighbourhood of Oakes' Find is not one, and that Devonian and perhaps Ordovicion fossiliferous rocks may subsequently be found between the Carboniferous and Cambrian in the district.

It will be realised, therefore, that the importance of an accurate determination of the stratigraphy of the district cannot be exaggerated, and the results of further geological work will be awaited with great interest.

V.—SIMILAR OCCURRENCES OUTSIDE THE STATE.

Up till a short time ago there was a tendency to regard this particular occurrence of impsonite as unique. The original mineral described from eastern Indian Territory, U.S.A., in 1898‡, though very similar to that at Oakes' Find, occurs as a vein in a body of greenish clay shales that are included between sandstones 100 to 150 feet apart, that are regarded as of Ordovician age and that are overlain by fossiliferous Ordovician limestone. This original mineral, therefore, occurs in a manner quite different from the impsonite at Oakes' Find.

In a Report on the Prospect of Finding Oil in South Karroo, in South Africa, Dr. A. W. Rogers mentions the fact that in the Beaufort Series, the so-called "coal" of Buffel's Kloof is a hard bright substance filling fissures, likes the "intrusive anthracite" of Laingsburg and Beaufort West Divisions. Up to the present no detailed account of the material from these localities has been found, though there is little doubt that it closely resembles the material from Oakes' Find.

Quite recently, however, there was published in the Transactions of the Geological Society of South Africa an article§ written

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* Report on the Geology of the Northern Territory: Bull. Northern Territory, No. 4, p. 20, by W. G. Woolnough, D.Sc.

† See footnote regarding localities (*ante*). ‡ Loc. cit.

§ On the Occurrence of Oil on Madrid Farm No. 281, in the Bethlehem District of the Orange Free State: by A. L. Hall, M.A., F.G.S., Trans. Geol. Soc., South Africa, Vol. XXIV., 1921, p. 98.

by Mr. A. L. Hall in which, after giving a short account of previous references to oil being found in igneous rocks in South Africa, Mr. Hall has described an occurrence of oil and oil residuum having such a striking resemblance to the one in East Kimberley that a short account of it will not be out of place.

The situation of the discovery is at Madrid Farm No. 281, about 30 miles S.S.E. of Bethlehem in the Orange Free State. The rocks of this district belong to the Stormberg Series of the Karroo System of Permo-Carboniferous age, and comprise the following in descending order:—

Basalts, amygdaloidal basalts and allied rocks.

Massive sandstones—Cave sandstone.

Soft purplish shaly sandstone.

Thin vertical basic dykes.

Resting directly on the Cave sandstone is a layer of dark volcanic rocks giving indications of oil in the form of a strong paraffin-like smell, smears of tarry matter, or small pockets of dark brown liquid bitumen (maltha).

The rock carrying the oil indications is a fine-grained nearly black basaltic variety with amygdules of quartz, zeolite, calcite, etc. In many instances a thin shell of nearly uniform width and of a compact black material surrounds the filling of the vesicles, and many vesicles are filled entirely by a black matter with no apparent zeolitic kernel. Some specimens show in a fine-grained basaltic ground-mass over 100 black vesicles which, being filled with a compact black shiny substance resembling coal, produce the impression of a rock that has caught up numerous xenoliths of this material. The larger vesicles are occupied by zeolitic or other amygdaloidal filling with a thin black shell, but nearly all the smaller vesicles are occupied wholly by the coaly-looking substance which is identical with the black shell. Not only the solid black material was found in the basalt, but actual pockets of liquid oil, and from one of the largest one gallon of oil could be siphoned off. During drilling and blasting the pockets are disturbed and their contents become spread out along joint and other divisional planes.

The basalt is of a proved maximum thickness of 42 feet on Madrid, and it is impregnated for a horizontal distance of 4,500 feet and for the whole of the thickness.

The thin vertical basic dykes are later in origin than the purplish clays, the Cave sandstone, and the basalt group.

Chemical analysis of the black constituent of the vesicles suggests that it is some hydrated silicate mineral which was partly altered with loss of crystalline structure and discoloured black by the infiltration of bituminous matter.

Mr. Hall concludes that the occurrence represents not a primary but a secondary deposit, and that the black material now filling the vesicles is not some carbonaceous substance caught up by the igneous rock, but an alteration product of the mineral which filled the vesicle prior to the impregnation of the rock by volatile hydrocarbons. The small amount of carbon still left in the altered amygdaloid is the residual base left after the removal of the volatile constituents. He further concludes that the impregnation of the basalt took place after the formation of the zeolite filling and one effect has been to partly or completely alter the minerals originally filling the vesicles into a black amorphous mass resemblying coaly matter. He regards the oil indications as most likely due to natural distillation from oil shales by the vertical basic dyke, or as the result of relief of pressure by means of fissures on shales in a condition of advanced potential distillation owing to deep burial below the surface.

The remarkable resemblance between the South African and Western Australian occurrences will be at once recognised. The most important differences are:—

(a) The basalt at Oakes' Find is in places sheared or shattered, and is apparently more strongly impregnated with impsonite where it is sheared than where it is massive.

(b) Both the age and the succession of the rocks are different, the basalt at Oakes being overlain by limestone and underlain directly or indirectly by Devonian or Cambrian.

(c) No basaltic dykes have been found in the district.

(d) The vesicles of the basalt are in part empty, in part filled with calcite, etc., in part completely filled by impsonite. There does not appear to have been any impregnation of vesicular fillings by hydrocarbons, the whole of the impsonite being homogeneous and without a trace of silicate or other minerals.

(e) In no instance was any liquid oil found in any of the vesicles, though of course the number of specimens examined was very small.

VI.—ORIGIN OF THE IMPSONITE.

In the present state of knowledge of the geology of the occurrence it is impossible to come to very definite conclusions as to the origin of the mineral. Nevertheless, there are certain facts having some bearing on the question which are worthy of mention.

The occurrence of the mineral in vesicles and along cracks in the rock shows that it must have been formed after the basalt had solidified, and, in part at least, after it had been more or less decomposed and disturbed by minor or local stresses. These facts, together with a consideration of the composition, structure, and conditions of formation of the basalt, indicate that the original oil was not formed in the basalt, but has entered it from some other source.

Further, the fact that the material is most common along zones of shearing or cracking in the rock, and that there is apparently some degree of impregnation of the rock substance in the vicinity of the shear zone, strongly suggests that the shearing has allowed of the penetration of the rock by the original hydrocarbons in fluid form. It is possible, of course, that these hydrocarbons existed in cavities in the basalt before the shearing and that the latter allowed of a movement of the fluid in the rock mass itself.

Moreover, if, following the example of most authorities, we put aside the inorganic origin of oil, then the original material which, by inspissation formed impsonite, must have been derived from limestones, sandstones, or carbonaceous or oil shales, whether fossiliferous or not. As only limestones that have been dolomitised, fissured or jointed are known to contain petroleum in any quantity, only those affected in these ways need be considered. In addition, it has been pointed out by Craig* and others that the absence of phosphates in the composition of petroleum as well as their absence in the vicinity of any large deposit of oil is evidence against the derivation of any considerable quantities of oil from a limestone source. Even more weighty evidence is the history of the deposition of limestone deposits.† As the present generation of lime-secreting organisms lives on the fatty remains of the preceding generation, directly or indirectly, there is little chance of the accumulation of fats. No trace of fats, for example, can be found in a coral bank except on the surface. On the other hand, the consumption of the remains of plant life, the decomposition of which is delayed sufficiently to permit the burial of a great deal of it before complete decomposition, does not proceed in the same manner as is shown by the great quantities of finely-divided carbonaceous matter throughout so many shale beds and other formations.

The limestones in the district, so far as investigations have shown, are not dolomitised, channeled or fissured, and contain only doubtful traces of impsonite in proximity to the basalt. Sandstones are reservoirs for oil produced from other formations rather than deposits from which hydrocarbons may be derived by distillation.

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* E. H. Cunningham Craig: Oil Finding.

† See Principles of Oil and Gas Production: Johnson and Huntley, p. 20.